GPM ground validation activity in Italy

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OUTLINE

National network application

- Development of a specialized GV site in Italy: the multidisciplinary atmospheric observatory at CNR-ISAC, Rome
- Potential of operational regional/national networks in Italy for ground validation

Physical validation

- Strategies for employing polarimetric radars in physical validation of satellite measurements

Integrated Validation

- Development and calibration of rainfall downscaling models

Synergies with others in the GV community

Summary and Recommendations for Collaboration

1. NATIONAL NETWORK APPLICATION

- **Objective:**

  Development of a specialized GV site in Italy: the multidisciplinary atmospheric observatory at CNR-ISAC, Rome within the context of regional and national operational measurement networks

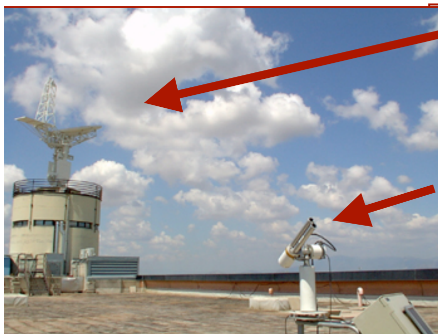
- Collaborating investigators

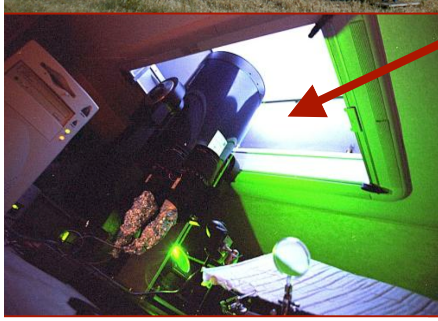
  National Research Council of Italy – Institute of Atmospheric Sciences and Climate, Rome

- Resources

  Synergy among different projects funded by the Italian Space Agency (ASI), the Department of Civil Protection, European Commission, Ministry of University and Research.

ISAC-CNR
Atmospheric observatory of Rome



Polar 55c

Multiple receiver lidar system using simultaneously the Rayleigh-Mie and Raman (RMR) techniques to profile aerosol (from few hundreds of meters up to the stratosphere), temperature (in the mesosph. and upper stratosphere) and Water Vapour in the entire troposphere.

CIMEL Sunphotometer a sky-scanning instrument measuring direct and diffuse solar radiation between 440 and 1020 nm to provide aerosol optical depth, precipitable water, aerosol size distribution, refractive index and single scattering albedo. Part of AERONET, the NASA-Goddard photometric network.

VHF Radar wind profiler a ground-based clear air Doppler radar that measures vertical profiles of horizontal and vertical wind by using five beams.

Ultrasonic anemometer-thermometer based on USA1 sensor by METEK GmbH determines the virtual temperature and wind speed and direction at high accuracy and to retrieve the sensible heat and momentum flux. **NET radiometer** by Kipp&Zonen with two pyranometers CM3, and two pyrgeometers CG3 suitably mounted to measure the incoming and outgoing SW and LW respectively

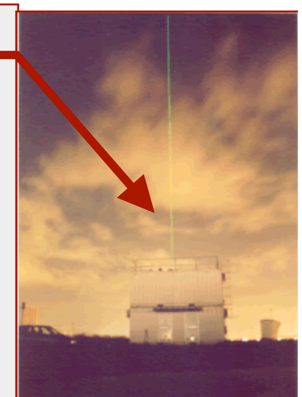
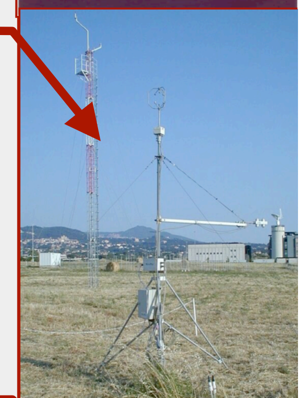
Automatic weather station for the measurement of standard atmospheric parameters and incoming LW and SW radiation.

Minisodar and sodar are acoustic remote sensors of Planetary Boundary Layer (PBL). They can provide a “snapshot" of the thermal structure of the PBL and the wind profile in the whole troposphere.

MTP5 (Meteorological Temperature Profiler) based upon the measurement of thermal radiation from the molecular oxygen absorption band (60.4 GHz) in the atmosphere gives the air temperature profile up to 600m.

VELIS (Vehicle-mounted Lidar System) is a mobile polarization lidar (532 nm) providing aerosol profiles between 150 m and 20 km. VELIS is operational since 1999, participating so far into five EU programs. When not engaged in field campaigns VELIS is continually operated at the ISAC Rome observatory.

Microlidar (µLID elastic backscatter lidar) measures from 0.5 to 10 km, according to background light conditions, the volume backscattering coefficient and volume depolarization at 532 nm.


Polar 55C radar

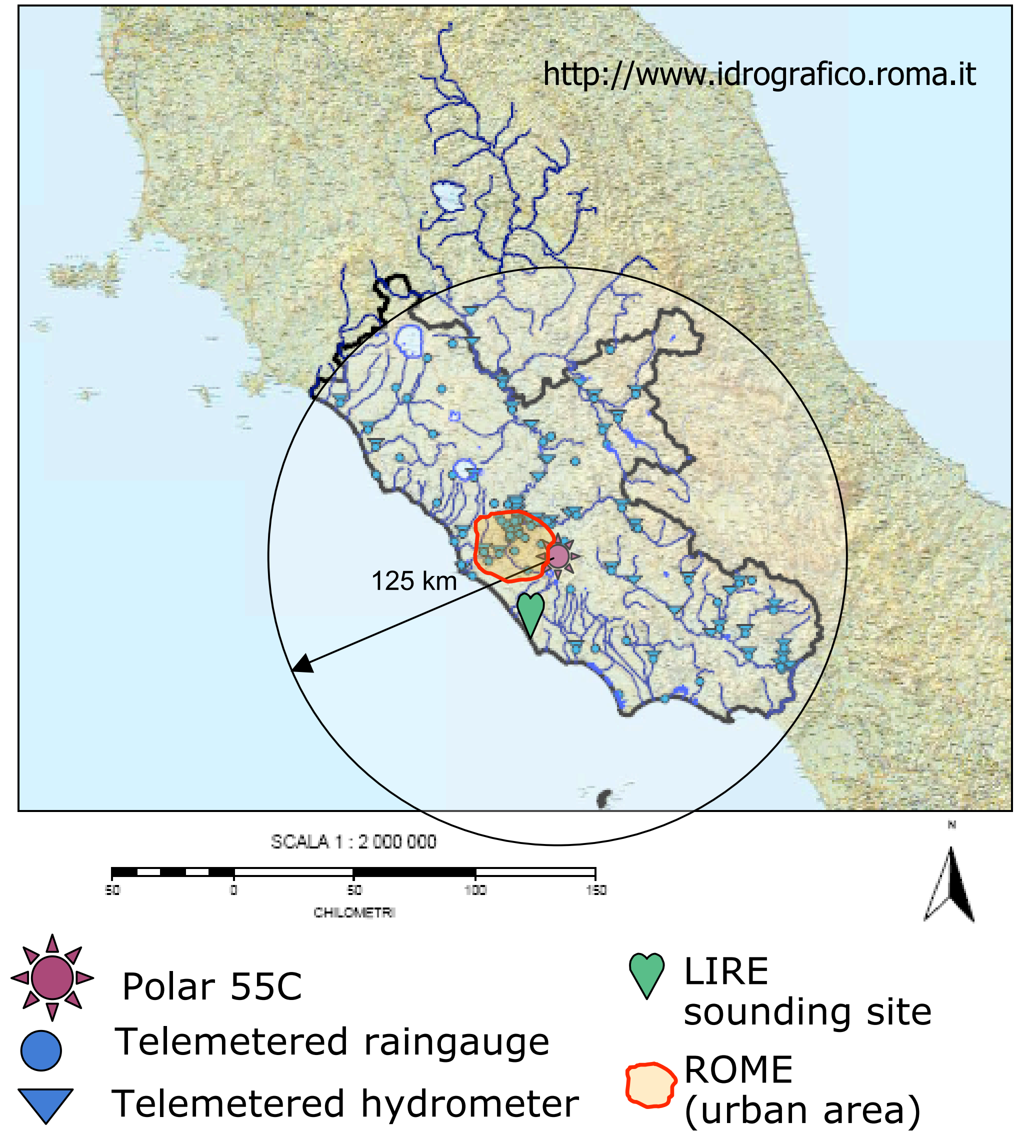
- Coherent dual polarization C-band radar
- Digital receiver since 2002
- Z_h, Z_{dr}, v, σ_v and Φ_{dp} measurements

Antenna	
Type	Offset fed Paraboloid
Feed	Corrugated horn
Aperture diameter	4.57 m
Polarization	Horizontal and Vertical
Azimuth beamwidth	0.92°
Elevation beamwidth	1.02°
Gain	45.5 dB
Sidelobe level	-32 dB
Cross Polarization	-27 dB
Transmitter	
Power Amplifier	Klystron VCK 7762
Frequency	Selectable: 5613, 5617, 5621, 5625, 5629, 5633, 5637, 5641 MHz. ±165KHz 5625 MHz in use (sel = 3)
Wavelength	5.3410, 5.3372, 5.3334, 5.3296, 5.3259, 5.3221, 5.3183, 5.3145 cm 5.3296 cm in use (sel = 3)
Peak Po wer	500 kW
Pulse width (maximum)	0.5 – 1.5 – 3.0 _s
PRF	1000÷1200 Hz with pulse width 0.5 _s 500 ÷ 600 Hz with pulse width 1.5 _s 250 ÷ 300 Hz with pulse width 3.0 _s:
Average Power	250÷300 Hz with pulse width 0.5 _s 375 ÷ 450 Hz with pulse width 1.5 _s 375 ÷ 450 Hz with pulse width 3.0 _s:
Receiver	
Number of channels	2: (RX nd TX sample down conversion to IF)
Noise figure	2.0 dB from the input of the first down conversion module.
Image Rejection	> 50dB
Dynamic range	100dB at 1dB compressi on
IF	60 MHz
IF bandwidth	2.0 – 0.7 – 0.5 MHz

Potential of operational regional networks for ground validation

- Networks managed by Regione Lazio (Ufficio Idrografico e mareografico)
    - Telemetered raingauge network (space resolution 10km^2 time resolution greater than 1 min)
    - Telemetered hydrographic network
- Instruments managed by Air Force
    - Sounding station 20 km South of Polar 55C site

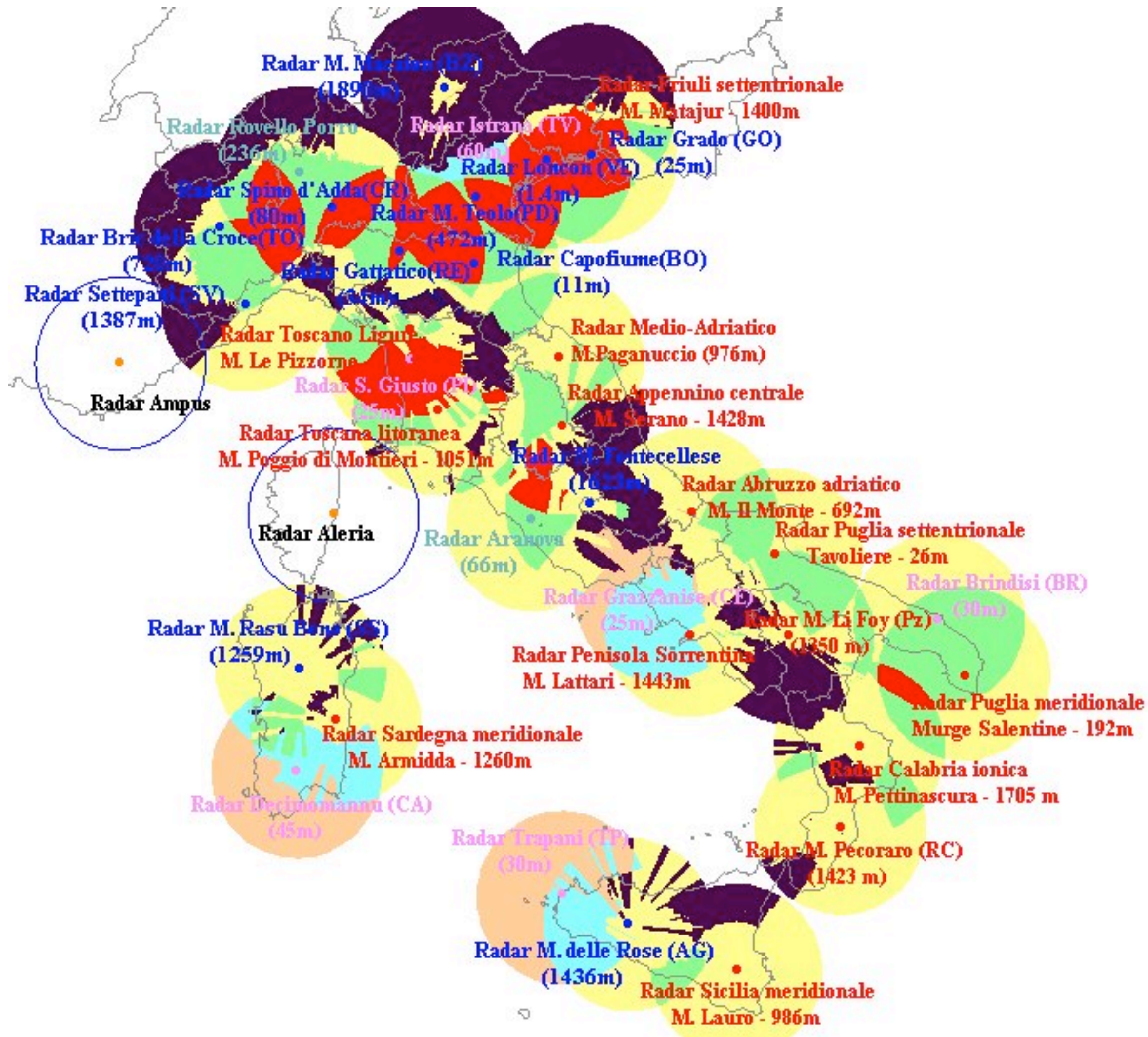
ISAC observatory is suitable to study the contributions of land-sea interaction and of urban areas in the cloud and precipitation formation mechanisms.

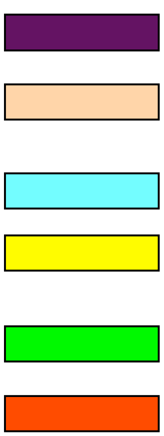


Potential of operational national networks for ground validation

The Meteo radar network of Civil Protection Department federates radars managed by regional authorities, Air Force and Civil aviation with radars managed by Department of Civil Protection.

The network include operational C-band dual polarization radars





2. PHYSICAL VALIDATION

- **Objective:**

  Strategies for employing polarimetric radar in physical validation of satellite precipitation estimate

- Collaborating investigators
  - National Research Council of Italy – Institute of Atmospheric Sciences and Climate
  - Colorado State University - Radar and Communications group
  - University of Florence

- Supported through projects funded by the Italian Space Agency

Example of GV activity within COSMO SkyMed (Italian Space Agency)

COSMO SkyMed: Constellation of 4 Small Satellites for Mediterranean basin Observations

Objective

"environmental monitoring, for management of exogenous, endogenous and anthropogenic risks"

Satellites launched in 2007, Jun 7, Dec 9.

Operating modes:

Stripmap: 3-15 m res. , scene: 40x40 km^2

Polarimetric: HH, VV, HV; 15-m res.; scene: 30x30 km^2

ScanSAR: 30-100 m res., scene: 200x200 km^2

GV objective

Polarimetric radar measurements of precipitation to characterize the uncertainty in the SAR precipitation estimate due to assumed cloud and terrain parameters

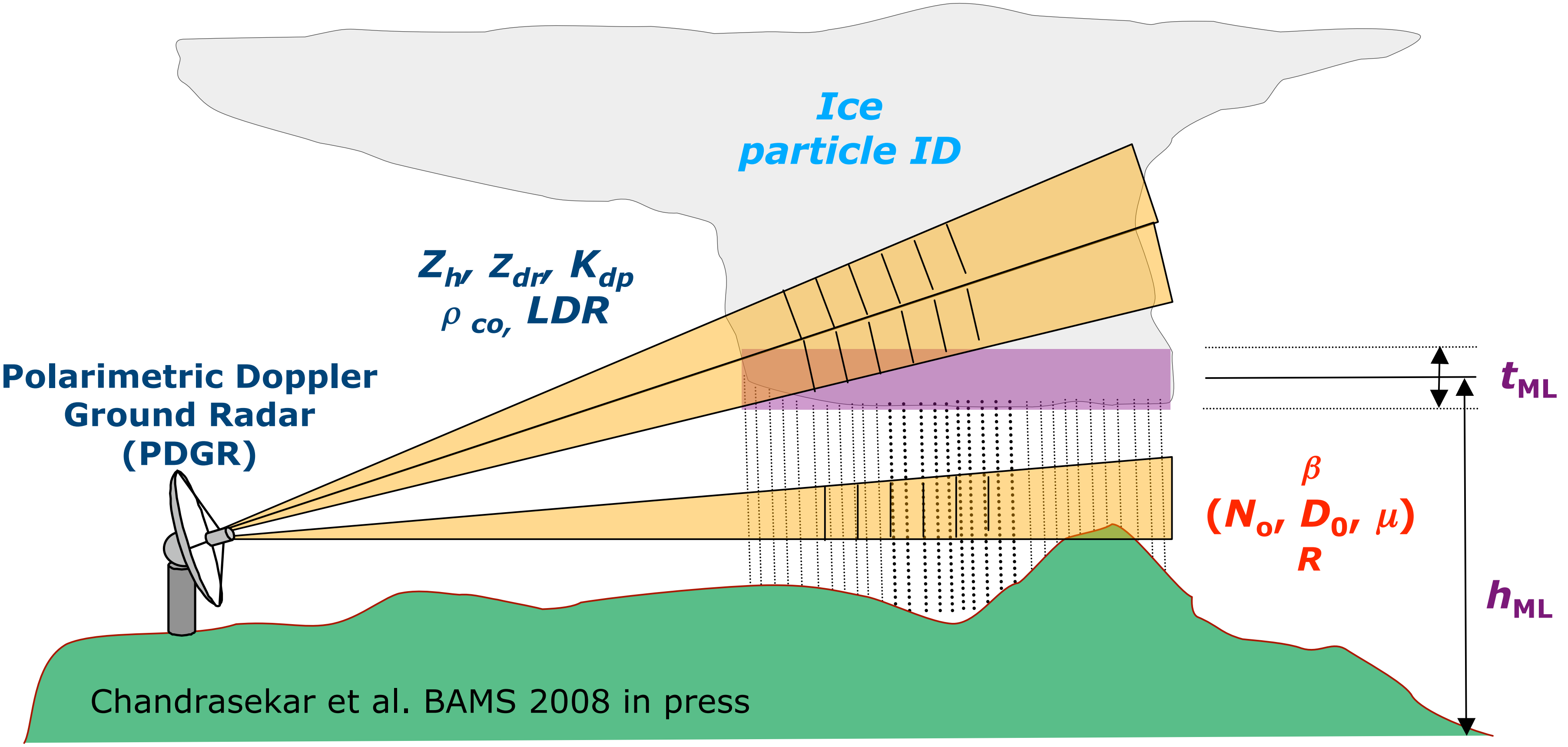
Activities

- Developing strategy for cross-validation of X-SAR and volumetric PDGR measurements
- Reconstruction of X-SAR measurements from volumetric microphysical observations
- Development of model and in-situ data base to characterize surface change observations due to precipitation
- Development of a neural-network methodology for the retrieval of precipitation
- Statistical characterization of retrieved precipitation fields by scale-invariance analyses

Cross-validation of satellite measurements and volumetric PDGR measurements

Polarimetric Doppler ground radars are capable of providing

- highly accurate precipitation estimate (*R*)
- insights into clouds and precipitation in terms of:
  - distribution of size and shape of raindrops (β, N_0, D_0, μ)
  - height and thickness of melting layer (h_{ML}, t_{ML})
  - hydrometeor classification below and above the melting layer



Cross-validation of satellite measurements and volumetric PDGR measurements

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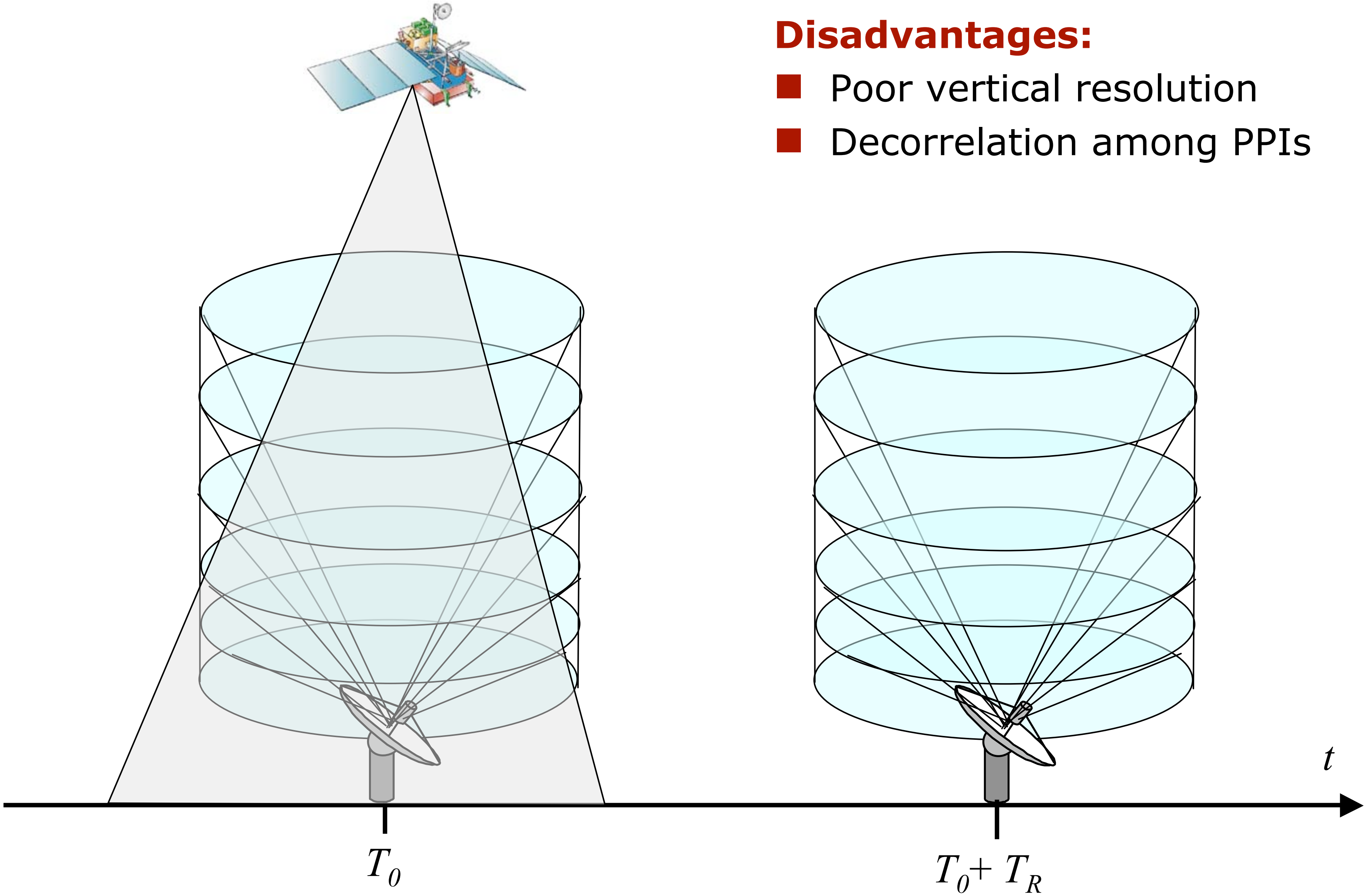
In Italy GV products will be derived from dual polarization **C-band radars** in **orographically complex contexts**. Critical issues are:

- Development of techniques to compensate the C-band propagation effects
- Development of techniques to deal with ground clutter and beam occultation

Chandrasekar et al. BAMS 2008 in press

Standard scanning strategy



Disadvantages:

- Poor vertical resolution
- Decorrelation among PPIs

GV scanning strategy

Vertical observations

➔**Height and thickness of Melting Layer**

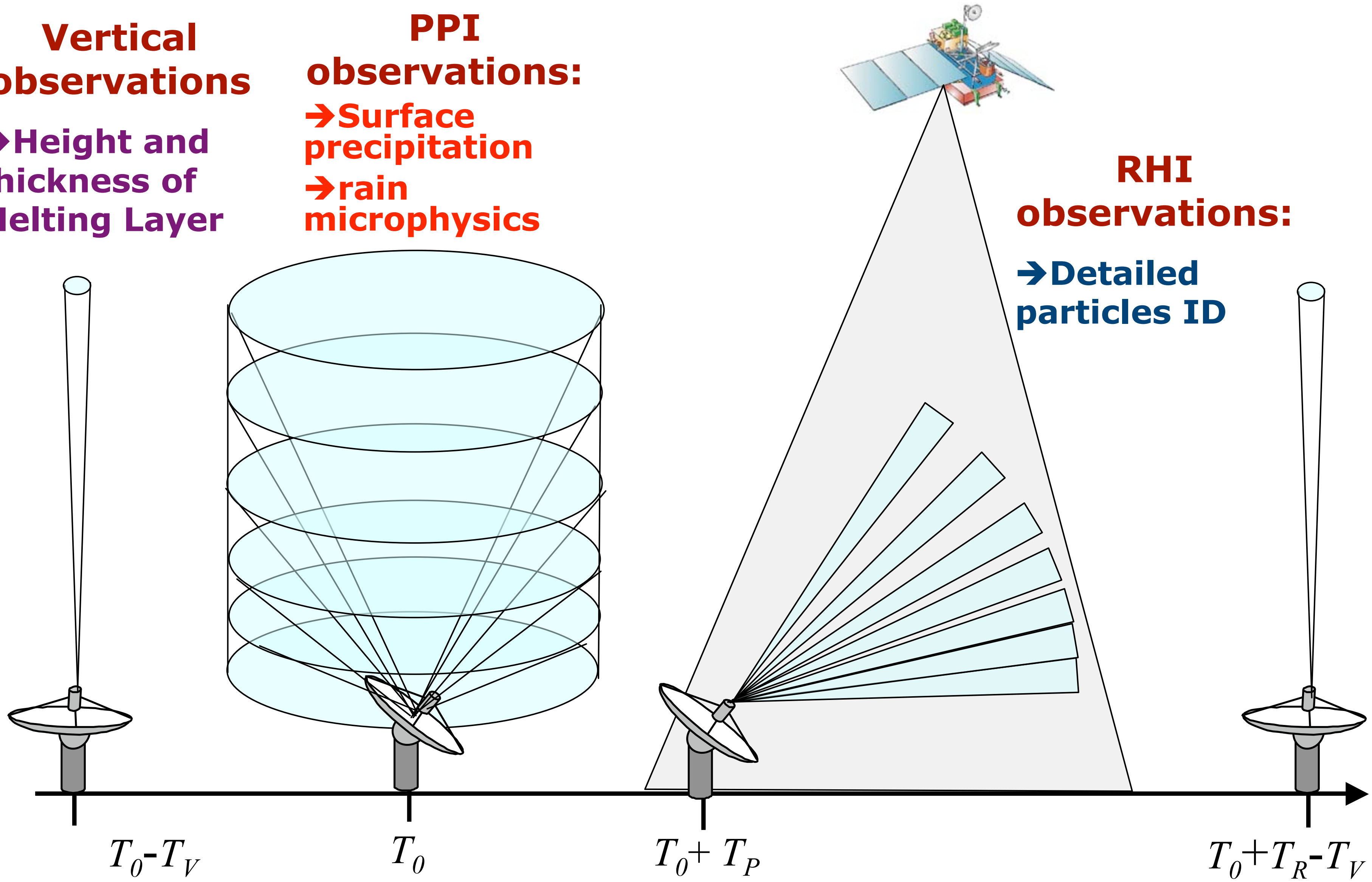
PPI observations:

➔**Surface precipitation**

➔**rain microphysics**

RHI observations:

➔**Detailed particles ID**



PPI observation: rain microphysics retrieval (1/2)

- For each rain path where Z_h, Z_{dr} and Φ_{dp} are available, the FSC correction method is used to estimate attenuation and differential attenuation to obtain corrected Z_h and Z_{dr} profiles;
- For each path, β is estimated

$$\beta = c_1 \left(\frac{K_{dp}}{Z_h} \right)^{a_1} \xi_{dr}^{b_1}$$

Z_h : mean power along the path

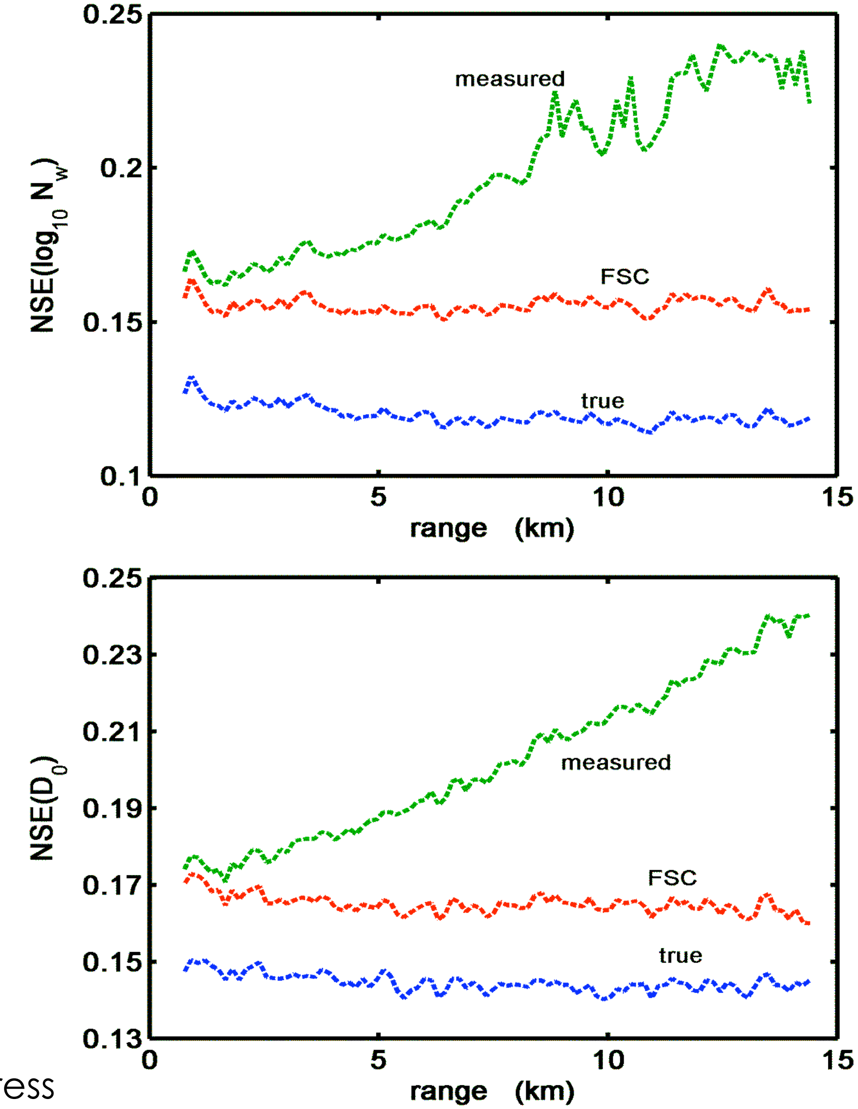
ξ_{dr} : ratio between the mean power at H and V polarization,

K_{dp}: mean value from the finite difference of Φ_{dp} profile

- In each range bin,

$$\log_{10} N_w = c_3 \left(\frac{\xi_{dr} - 0.8}{\beta} \right)^{a_3} Z_h^{b_3} \qquad D_0 = c_2 \left(\frac{\xi_{dr} - 0.8}{\beta} \right)^{a_2}$$

Beard & Chuang (1987) non-linear drop shape model



Gorgucci, Baldini and Chandrasekar, JTECH 2008 in press

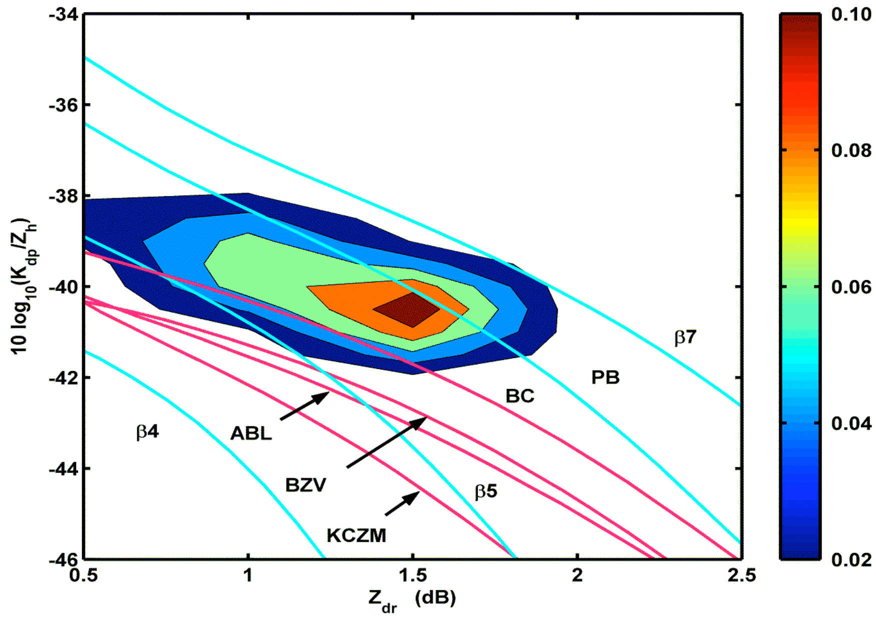
PPI observations: rain microphysics retrieval (2/2)

Linear models

PB	Pruppacher and Beard, 1970
β4	$\beta=0.04\text{mm}^{-1}$
β5	$\beta=0.05\text{mm}^{-1}$
β7	$\beta=0.07\text{mm}^{-1}$

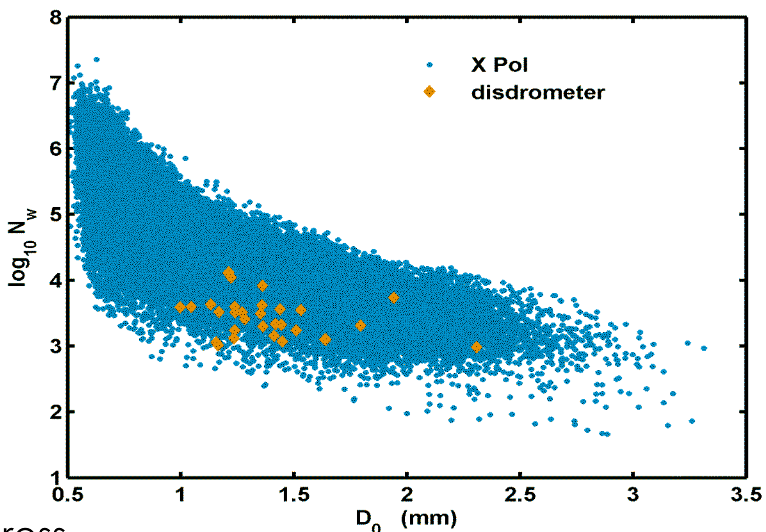
Non-linear models

BC	Beard and Chuang, 1987
ABL	Andsager et al.,1999, for 1<D<4, BC outside
KCZM	Keenan et al, 2001
BZV	Brandes et al., 2002



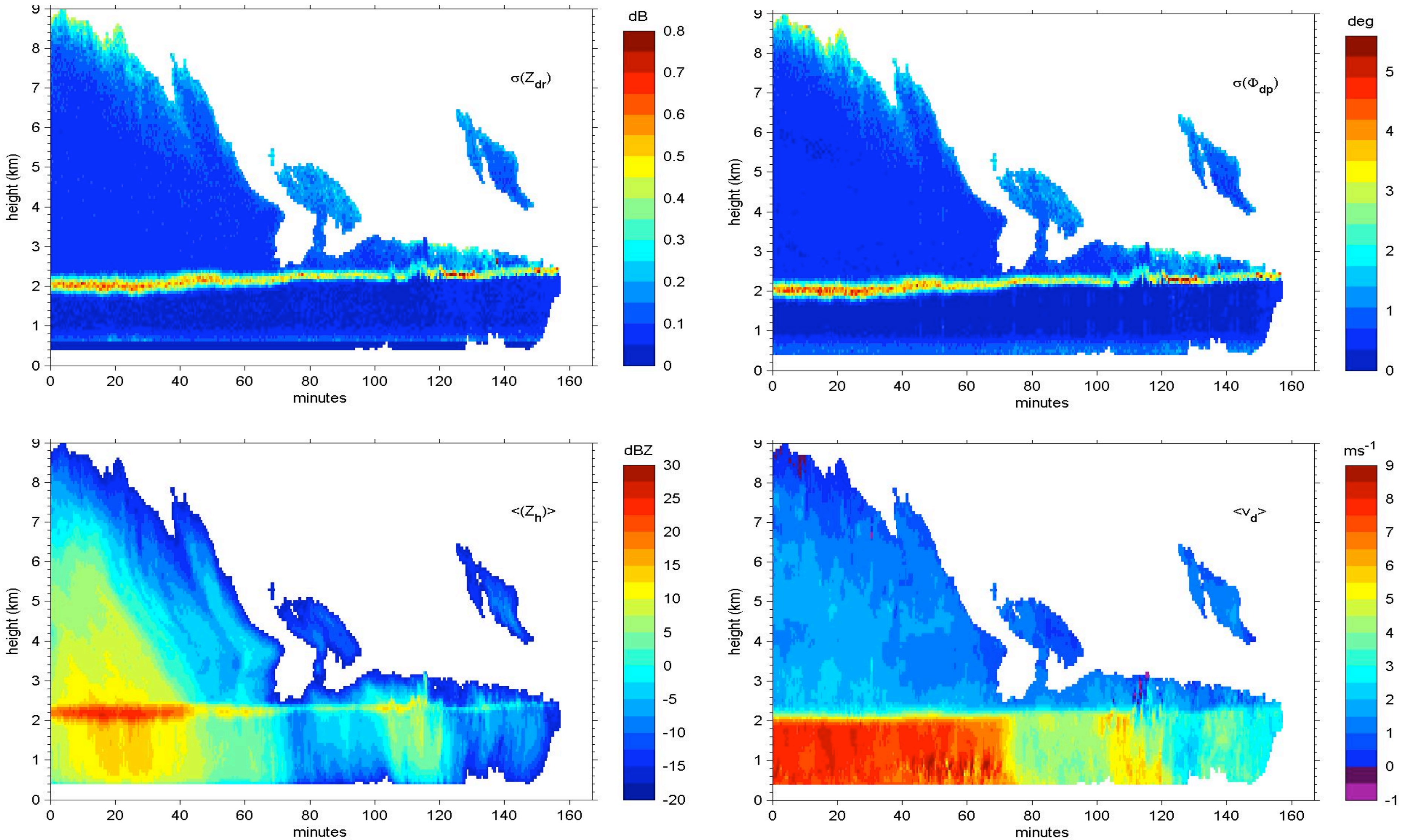
Scatter diagram between radar retrieved $\log_{10}N_w$ versus D_0
Superimposed are 5-minute-averaged log10N_w versus D_0 from a NASA Joss-Waldvogel disdrometer.
Disdrometer data refer to 3-hour measurements

(X Pol data)



Gorgucci, Baldini and Chandrasekar, JTECH 2008 in press

Vertical observations: Meting layer height and thickness

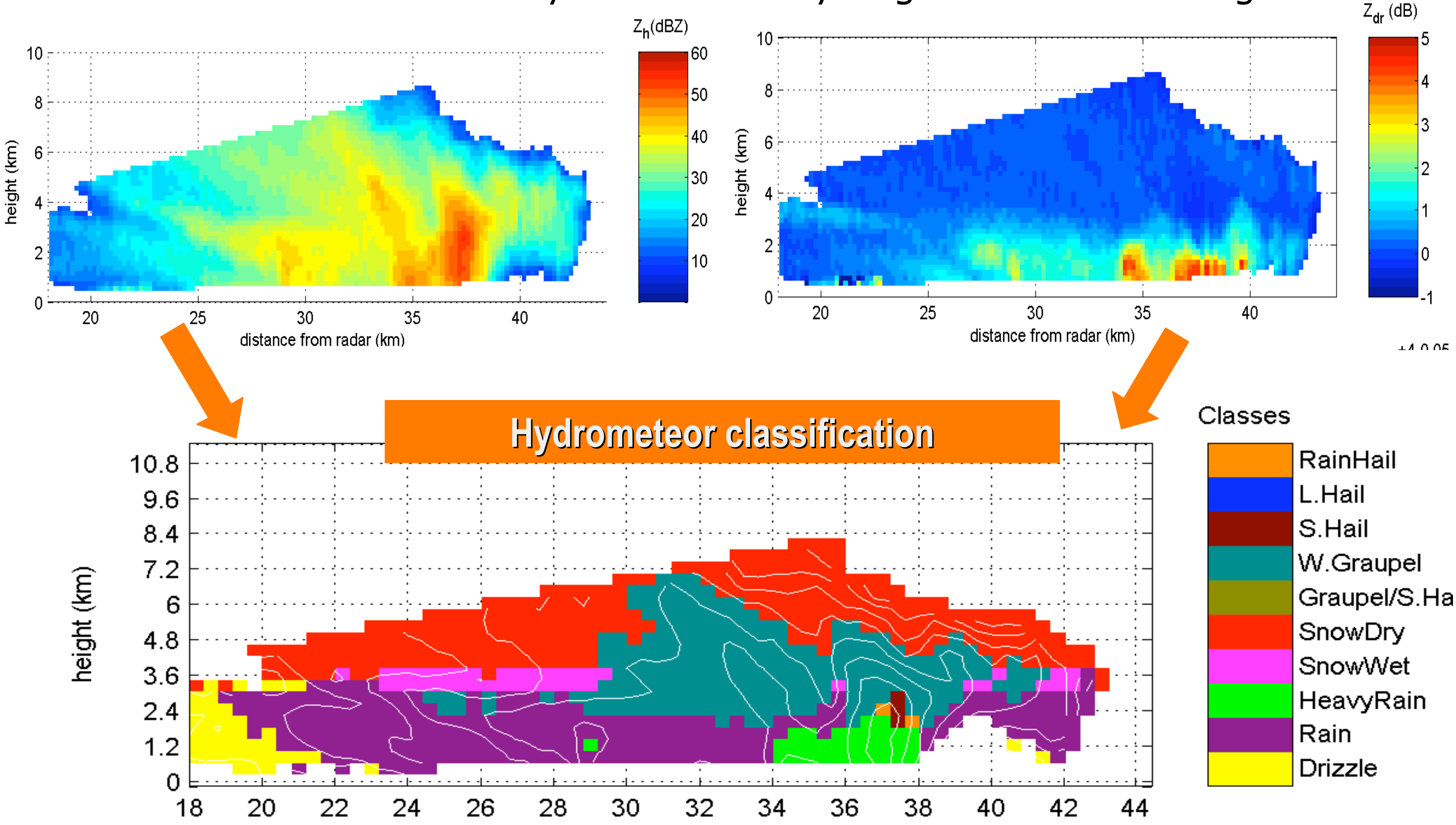


Baldini and Gorgucci, JTECH 2006

Polar 55C data

RHI observations: Hydrometeor Classification

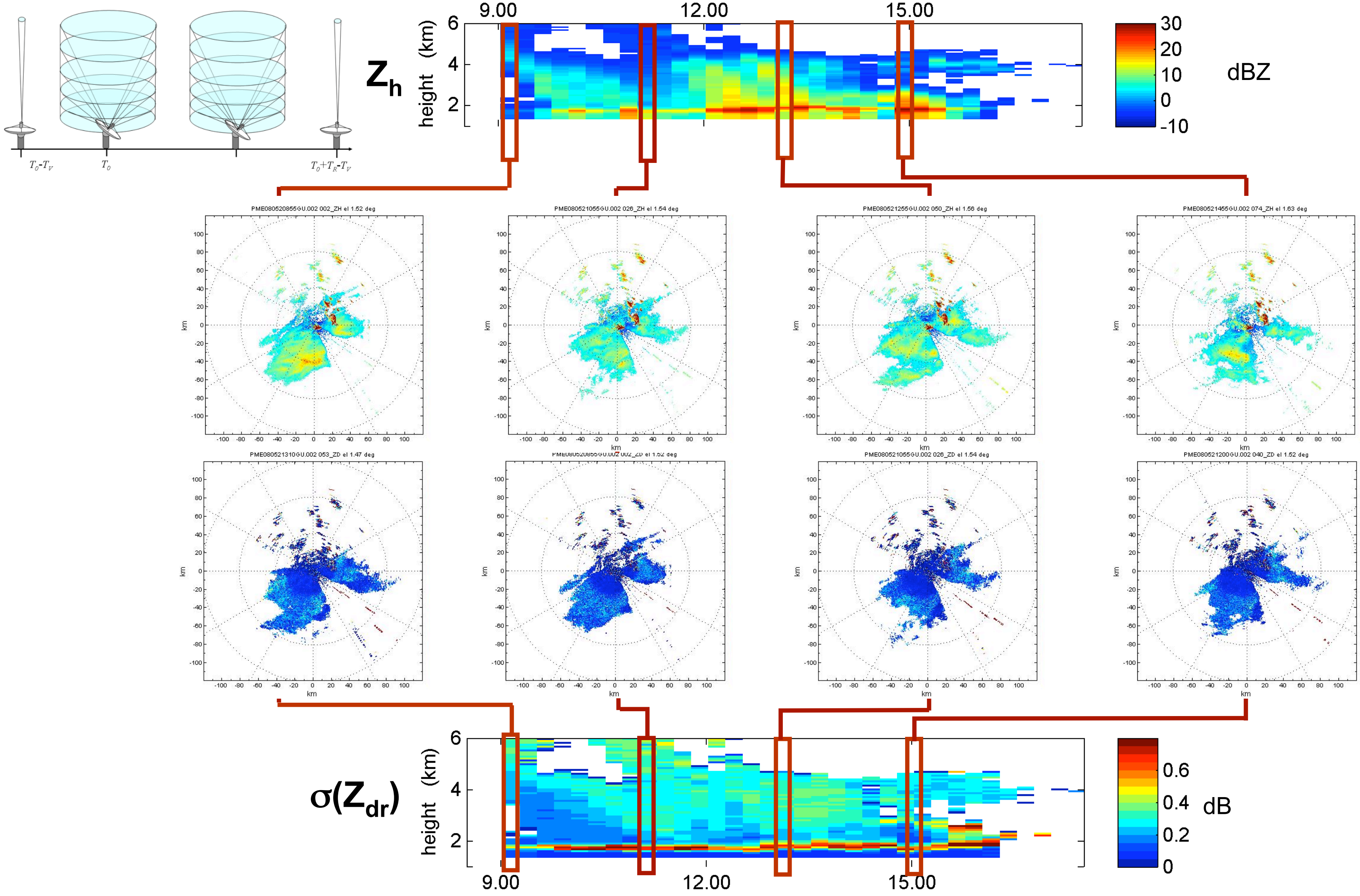
- C-band extension of a hybrid CSU fuzzy-Logic classification algorithm



From Baldini et al. 32 AMS Radar Conference

Polar 55C data

GV scanning strategy Example Feb 21, 2008



3. INTEGRATED VALIDATION

- **Objective:**

  Development and calibration of rainfall downscaling models

- Collaborating investigators
  - University of Cagliari, Department of Earth and Environmental Sciences
  - New Mexico Institute of Mining and Technology

- Activity supported through projects funded by the Italian Space Agency

Development and calibration of rainfall downscaling models

Why we need rainfall downscaling models?

Flood risk can be evaluated by hydrological models that require as input the rainfall forecasts by Numerical Weather Prediction (NWP) models.

NWP centres provide everyday rainfall fields at the following space resolutions**:**

- *General Circulation Models (GCM): about* ***25-40 km***
- *Hydrostatic Limited Area Models (LAM): about* ***10 km***
- *non-hydrostatic high-resolution LAMs: about* ***2-5 km***

For hydrological purposes the last resolution (few km) should suffices.

... but the smaller the scale, the larger the forecast errors :

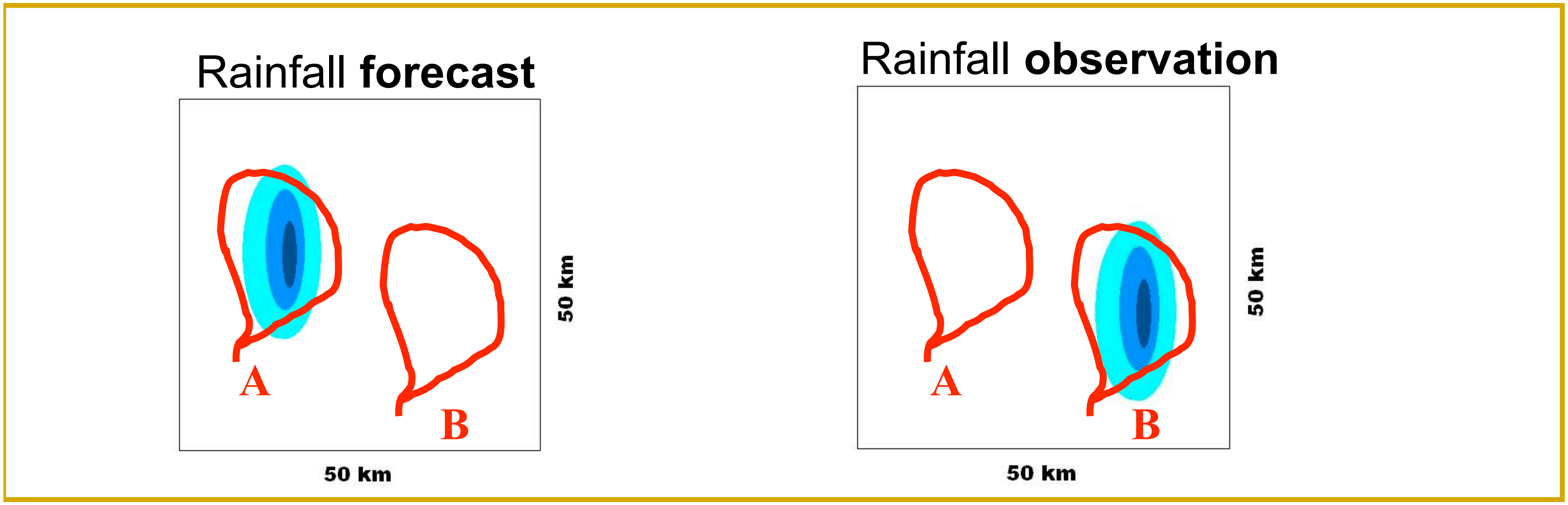
- *limits of predictability (errors increase with a power law as scale decreases)*
- *coarseness of the observational network used to build analyses*
- *models are not reliable at their own resolution (e.g. for numerical diffusion* $\nabla^4\phi$*)*

Common NWP forecast errors in rainfall fields:

- *wrong localization of rainfall peaks in space*
- *wrong time of occurrence of rainfall peaks*
- *wrong volumes of rainfall at model grid scales*

Development and calibration of rainfall downscaling models

- Significance of errors and uncertainty of NWP models with a simple example



If the volume of water in the 50x50 km box is the same, <u>it is a good meteorological forecast!</u>

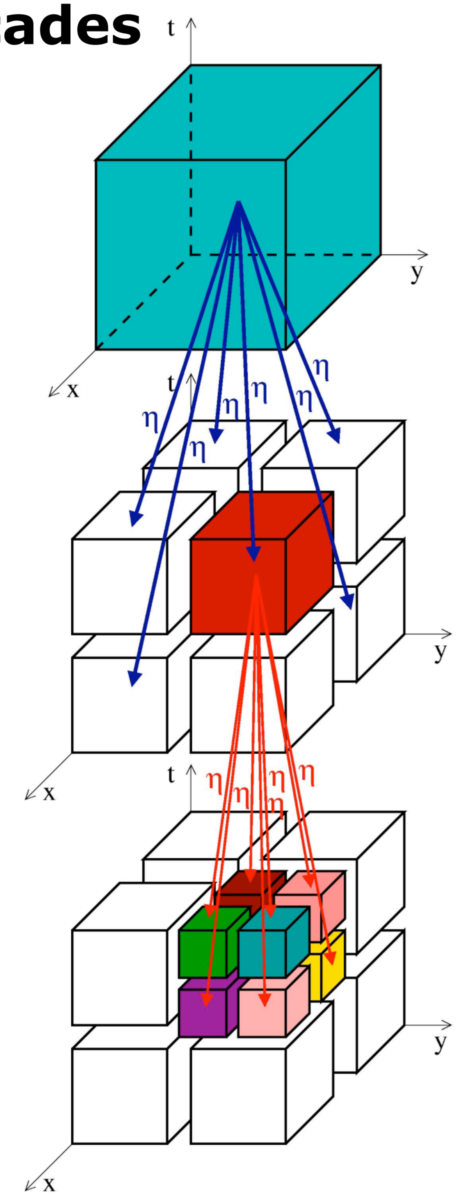
But, if A and B are two catchments, the flood prediction will be wrong.

<u>For hydrological applications we cannot accepts this kind of errors</u>

→ **Rainfall fields should be aggregated up to a reliable space-time scale and then disaggregated to small scale preserving observed statistics**

Development and calibration of rainfall downscaling models

Downscaling models based on multifractal cascades



EVIDENCE:

*Rainfall fields display **fluctuations in space and time** that increase as the scale of observation decreases.*

***Some statistical properties observed** in rainfall fields **follow scale-invariance laws** that control how intensity fluctuations can increase at smaller scales of space and time.*

METODOLOGY

***Multifractal theory** represents a solid base **to characterize** scale-invariance properties observed in rainfall fields and can be used **to develop** downscaling models able to reproduce observed statistics (e.g. **multifractal cascades**).*

Multifractal cascades (refer to Figure):

Cubes represent space(x,y)-time(t) grids

TOP: aggregated rainfall volume at a reliable large scale

*MIDDLE: rainfall volumes at smaller cubes are the product of the father volume (top) by a **stochastic generator (η)***

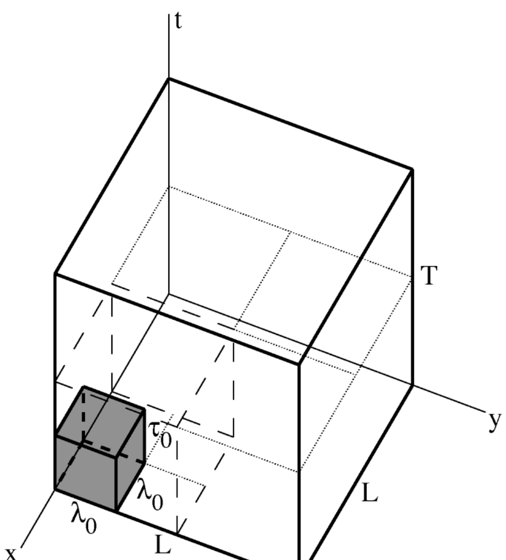
*BOTTOM: rainfall volumes are originated by middle cubes (now fathers) by a **stochastic generator (η)***

…….. the procedure can be iterated several times …

Development and calibration of rainfall downscaling models

Calibration of rainfall downscaling models

Multifractal analyses require High resolution rainfall fields (both in time and space)

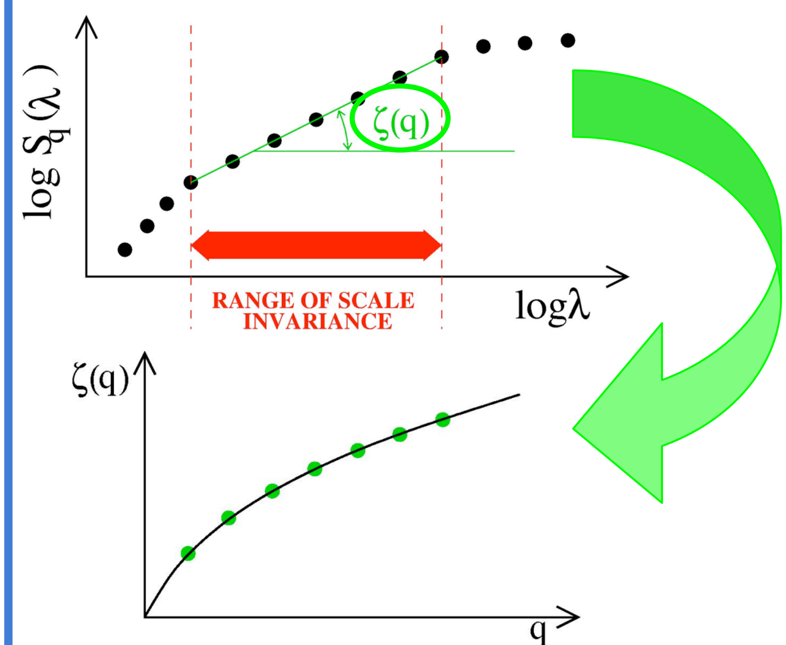


$$\mu_{i,j,k}(\lambda) = \int_{x_i}^{x_i+\lambda} dx \int_{y_j}^{y_j+\lambda} dy \int_{t_k}^{t_k+\lambda/U} dt \;\; i(x,y,t)$$

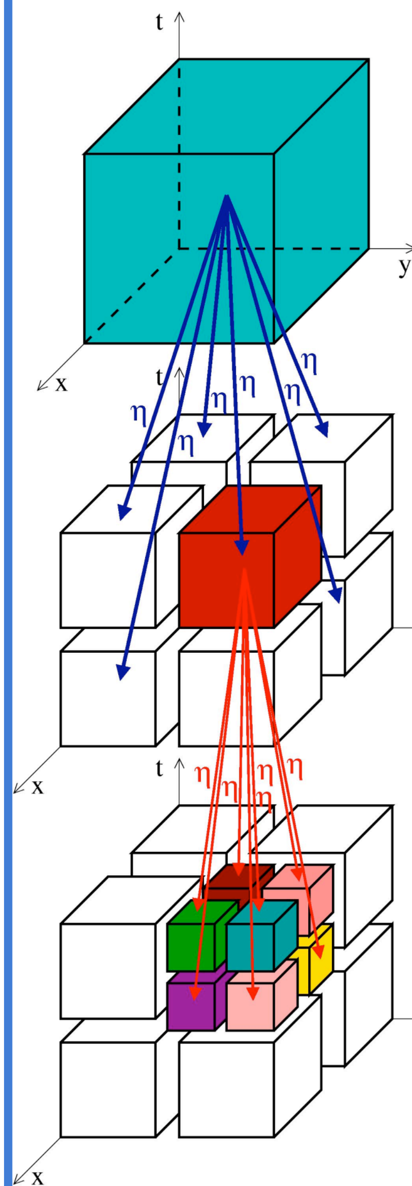
Rainfall volumes μ must be computed on wide ranges of scales (cube sizes)

Partition function & scale invariance:

$$S_q(\lambda) = \left\langle \mu_{i,j,k}(\lambda)^q \right\rangle \approx \lambda^{\xi(q)}$$



ζ(q) are multifractal exponents:
They are used to CALIBRATE the cascade generator η



Development and calibration of rainfall downscaling models

Contribution of GPM to rainfall downscaling models

- The operational applications of rainfall downscaling models based on multifractal cascades require a “rule” for the generator η.
- Relationships to calibrate η in terms of empirical functions of large scale rainfall rate or CAPE have been proposed. There is a lack of systematic studies for worldwide calibration of multifractal cascades: most proposed relationships refer to small study-areas.
- Satellite constellations represent a useful source of high resolution rainfall data for calibrating rainfall downscaling models capable to correctly reproduce reliable small scale statistical properties.

Contribution of multifractal world to GPM GV

- Multifractal theory and scale-invariance analyses provide powerful tools for characterization of rainfall fields over wide ranges of scales in space and time.
- The multifractal approach is thus particularly suitable to assess the reliability of satellite data and to perform comparisons with other sources of data such ground radar and other kinds of ground based instrumentation

Synergies with others in the GV community

On national basis

- To stimulate the involvement of national science community in the GV activity to create an Italian multidisciplinary GV community
- To improve observational capability of CNR-ISAC observatory
- To strenghten the coordination with operational national networks

On international basis

- Synergies with some partners (eg CSU for dual-pol radars and NMIMT for rain downscaling) have been established
- Need to enlarge efforts with EU partners especially in the Mediterranean Region

Summary and recommendations for collaboration

- A GV site operating in Rome with proper instrumentation has been presented

- Concepts for physical validation of satellite measurements are being developed and applied within other satellite missions

- Multifractal approach is used to assess the reliability of satellite data and to perform comparisons of satellite estimated with ground radar

- **Recommendations for collaboration**
  - Importance of GV in Mediterranean region
  - Radar based GV activities at attenuating frequencies